AVT Bonito

Technical Manual

High-speed high-resolution CMOS Camera

V2.2.1

11 May 2012

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ALLIED Vision Technologies

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Contacting Allied Vision Technologies

Info

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Introduction

This **Bonito Technical Manual** describes in depth the technical specifications, dimensions, all pixel formats, bandwidth and frame rate related subjects.

Note **Please read through this manual carefully.**

Document history

Version	Date	Remarks
V2.0.0	03.11.11	New Bonito Technical Manual
V2.1.0	23.01.12	• Corrected Power supply values and mass values in Chapter Bonito CL-400B/C, Bonito CL-400B/C 200fps on page 12 • Added F-Mount in legend of Figure 5: Bonito CL-400B/C C-/F-/EF-Mount (back) on page 17 • Corrected power supply values in: – Chapter Accessories on page 20 – Chapter Camera I/O connector pin assignment (15-pin D-Sub jack) on page 23 – Chapter Power supply (pin 1-4) on page 23 • Marked pin 5,6 and 14,15 as Reserve in Chapter Camera I/O connector pin assignment (15-pin D-Sub jack) on page 23 and changed description in Chapter Reserve I/O (pin 5, 9 and 14-15) on page 26 **Some minor corrections in** • Chapter Fixed Pattern Noise (FPN) Correction (C) on page 36 • Chapter Number of lines (N) on page 46 • Chapter Camera Link output mode setting (S) on page 47
to be continued on next page		

Table 1: Document history

Version	Date	Remarks
continued from last page		
V2.2.0	03.05.12	**Added description of new features in camera firmware V1.0.7** • Changed max. current from 0.36 A to 0.4 A: – Description to power supply: see Chapter Bonito CL-400B/C, Bonito CL-400B/C 200fps on page 12 – Chapter Accessories on page 20 – Chapter Power supply (pin 1-4) on page 23 • Pin 6 changed from Reserve to Sync: see Chapter Camera I/O connector pin assignment (15-pin D-Sub jack) on page 23ff. • Chapter Synchronization output (pin 6) on page 24 • In Chapter Exposure output (pin 12-13) on page 25: added Note This output is not recommended for new system designs. on page 26. • Added Chapter Synchronization output (J) on page 39 • Updated the following chapter to new bit field order: Chapter Exposure control mode (M) on page 40 • Range from N=0 (not N=1) in Chapter Number of lines (N) on page 46 • Added values 5 and 7 in Chapter Camera Link output mode setting (S) on page 47 • In Chapter Reset to factory defaults (Z) on page 51: Corrected E=000006BE (not 000006C1), F=000006BF (not 000006C2) Inserted J=01 and S=00 • Added new command reference description in Chapter Command reference on page 56 • Added hyperlink to AVT website for DeviceConfig in Chapter Serial I/O on page 20 • Changed AOI to ROI in the whole manual
to be continued on next page		

Table 1: Document history

Version	Date	Remarks
		continued from last page
V2.2.1	11 May 2012	• Some minor corrections • Added 80 bit to Camera Link Full+ – Chapter Bonito CL-400B/C, Bonito CL-400B/C 200fps on page 12 • Added 80 bit to clearly describe the 10-tap configuration of the Camera Link standard: – Chapter Camera Link interface (01-04 or CL1, CL2) on page 27 – Chapter Camera link connectors and 10-tap pin assignment on page 27 – Table 18: Output mode setting (S) on page 47 • Added example drawing: see Figure 12: Example conversion circuit from +/- 6 V RS232 output to 5 V TTL input on page 24 • Added information *to use exact multiples oft the current line duration*: see Chapter Timer prescaler value (K) on page 39 • Changed +/-2 t_L to t_L in Table 13: Exposure control modes: Exposure timing mode (bit group: e) on page 41 • Added *rising edge* description (bit group e, value=2): see Image on demand mode (IOD) with exposure timer on page 42 • Added more precise description of PIV mode: see PIV mode = On on page 44. • Added new Chapter Product variant code (b) on page 52. • Added new Chapter Command reference on page 56ff.

Table 1: Document history

Manual overview

This **manual overview** outlines the contents of each chapter of this manual.

- Chapter Contacting Allied Vision Technologies on page 5 lists AVT contact data (phone numbers and URLs) for both:
  - Technical information / ordering
  - Commercial information
- Chapter Introduction on page 6 (this chapter) gives you the document history, a manual overview (short description of each chapter) and conventions used in this manual (styles and symbols).
- Chapter Conformity on page 11 gives you information about conformity of AVT cameras (CE, FCC, RoHS).
- Chapter Specifications on page 12 lists camera details and measured spectral sensitivity diagrams for each camera type.

- Chapter Camera dimensions on page 15 provides CAD drawings of standard housing models (2D drawings and 3D isometric drawings), tripod adapter and cross sections of CS-Mount and C-Mount. Furthermore you find information on adjustment of C-Mount and CS-Mount.
- Chapter Camera interfaces on page 19 describes in general the inputs/ outputs of the cameras (incl. trigger features).
- Chapter Index on page 65 gives you quick access to all relevant data in this manual.

Conventions used in this manual

To give this manual an easily understood layout and to emphasize important information, the following typographical styles and symbols are used:

Styles

Style	Function	Example
Bold	Programs, inputs or highlighting important things	**bold**
Courier	Code listings etc.	`Input`
Upper case	Register	REGISTER
Italics	Modes, fields	*Mode*
Parentheses and/or blue	Links	(Link)

Table 2: Styles

Symbols

Note This symbol highlights important information.

Caution This symbol highlights important instructions. You have to follow these instructions to avoid malfunctions.

www

This symbol highlights URLs for further information. The URL itself is shown in blue.

Example:

http://www.alliedvisiontec.com

Before operation

Target group

This **Technical Manual** is the guide to detailed technical information of the camera and **is written for experts**.

Note

Please read through this manual carefully before operating the camera.

Caution

Before operating any AVT camera read the following **safety instructions** and **ESD warnings.**

Safety warnings

Caution

Electrostatic discharge

The camera contains sensitive electronic components which can be destroyed by means of electrostatic discharge.

Use sufficient grounding to minimize the risk of damage.

Conformity

Allied Vision Technologies declares under its sole responsibility that all standard cameras of the **Bonito** family to which this declaration relates are in conformity with the following standard(s) or other normative document(s):

- CE, following the provisions of 2004/108/EG directive
- RoHS (2002/95/EC)

CE

We declare, under our sole responsibility, that the previously described **Bonito** cameras conform to the directives of the CE.

Specifications

Note

The correct polarity of the 12 V supply voltage must be assured.

The warranty becomes void in case of unauthorized tampering or any modifications not approved by the manufacturer.

Bonito CL-400B/C, Bonito CL-400B/C 200fps

Feature	Specification
Image device	Type 4/3, CMOS progressive with global shutter
Effective chip size	**16.24 mm (H) x 12.08 mm (V)**
Cell size	7 µm x 7 µm
Picture size (max.)	2320 (H) x 1726 (V)
Lens mount	C-Mount, Canon EF-Mount, Nikon F-Mount
Frame rate	**Bonito CL-400B/C:** up to 386 fps, higher rates with smaller ROI **Bonito CL-400B/C 200fps:** with one Camera Link channel: up to 193 fps
ADC	10 bit
Exposure time	1.5 µs ... approx. 1 s
Operating temperature	0 °C ... +45 °C
Storage temperature	-30 °C ... +70 °C
Humidity (operating and storage)	max. 95% RH, non-condensing
Power supply	12 V DC, -10% ... +5%, 0.35 A (4.2 W), max. 0.4 A
Digital output	**Bonito CL-400B/C:** 2 x 10-tap Camera Link Full+, 80 bits, 80 MHz, 8 bits per pixel **Bonito CL-400B/C 200fps:** 1 x 10-tap Camera Link Full+, 80 bits, 80 MHz, 8 bits per pixel
Camera control	CC1: trigger input, CC2: reserve
Serial control	Serial via Camera Link or RS232 via control connector
Optocoupler inputs	1 external trigger input
Optocoupler outputs	1 exposure active signal

Table 3: Specification **Bonito CL-400B/C**, **Bonito CL-400B/C 200fps**

Feature	Specification
Smart features	ROI (Region of Interest), fixed pattern noise (FPN) correction, digital gain (selects 8 of 10 bits for output), offset (brightness), continuous mode (image acquisition with maximum frame rate), image on demand mode (triggered image acquisition)
Dimensions	44.2 mm x 80 mm x 70 mm (C-Mount) 71 mm x 80 mm x 70 mm (EF-Mount) 73.5 mm x 80 mm x 70 mm (F-Mount)
Mass	**Bonito CL-400B/C** (C-Mount): ~360 g **Bonito CL-400B/C** (EF-Mount): ~410 g **Bonito CL-400B/C** (F-Mount): ~390 g **Bonito CL-400B/C 200fps** (C-Mount): ~350 g **Bonito CL-400B/C 200fps** (EF-Mount): ~400 g **Bonito CL-400B/C 200fps** (F-Mount): ~380 g
Regulations	CE, RoHS (2002/95/EC)

Table 3: Specification **Bonito CL-400B/C**, **Bonito CL-400B/C 200fps**

Note

The design and specifications for the products described above may change without notice.

Caution

The camera contains sensitive electronic components which can be destroyed by means of electrostatic discharge (ESD). When handling the camera one has to take care of a sufficient grounding which is obligatory to minimize the risk of damage.

Spectral sensitivity

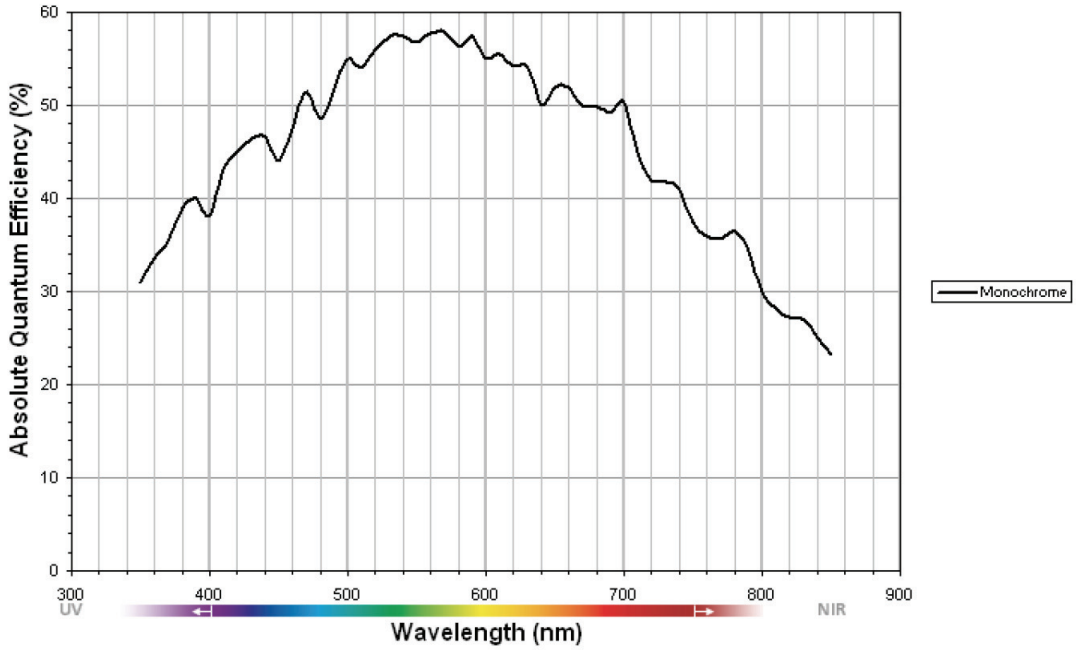


Figure 1: Spectral sensitivity of **Bonito CL-400B**

Note

Due to the sensor manufacturer, the spectral sensitivity curve for the color sensor is not available.

Camera dimensions

Bonito CL-400B/C C-Mount

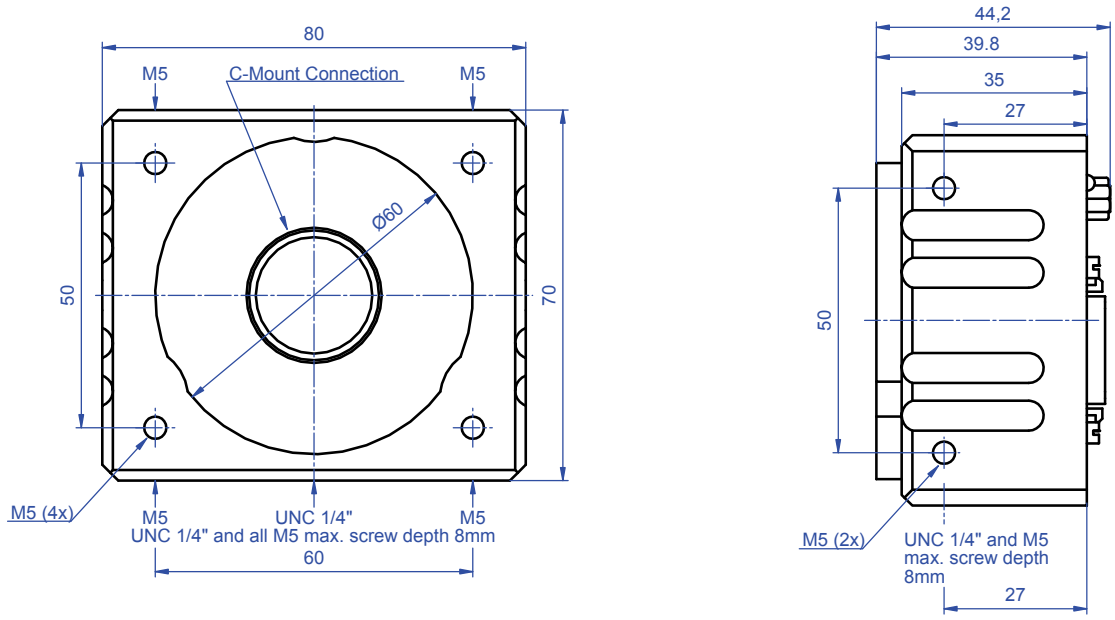


Figure 2: Camera dimensions: **Bonito CL-400B/C** C-Mount (front/side)

Bonito CL-400B/C EF-Mount

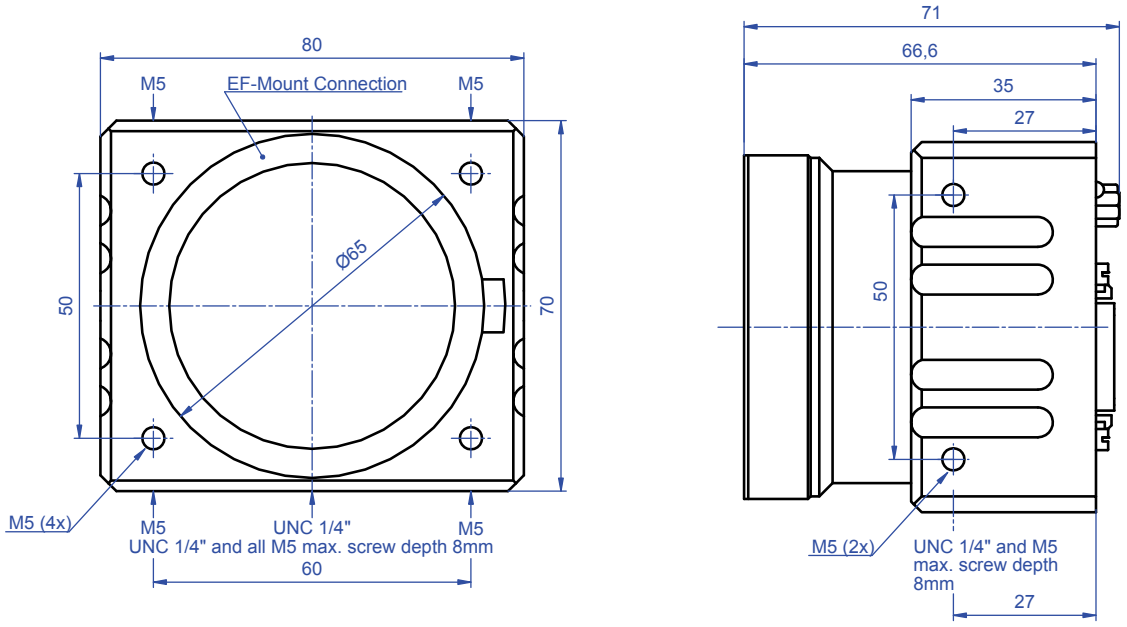


Figure 3: Camera dimensions: **Bonito CL-400B/C** EF-Mount (front/side)

Bonito CL-400B/C F-Mount

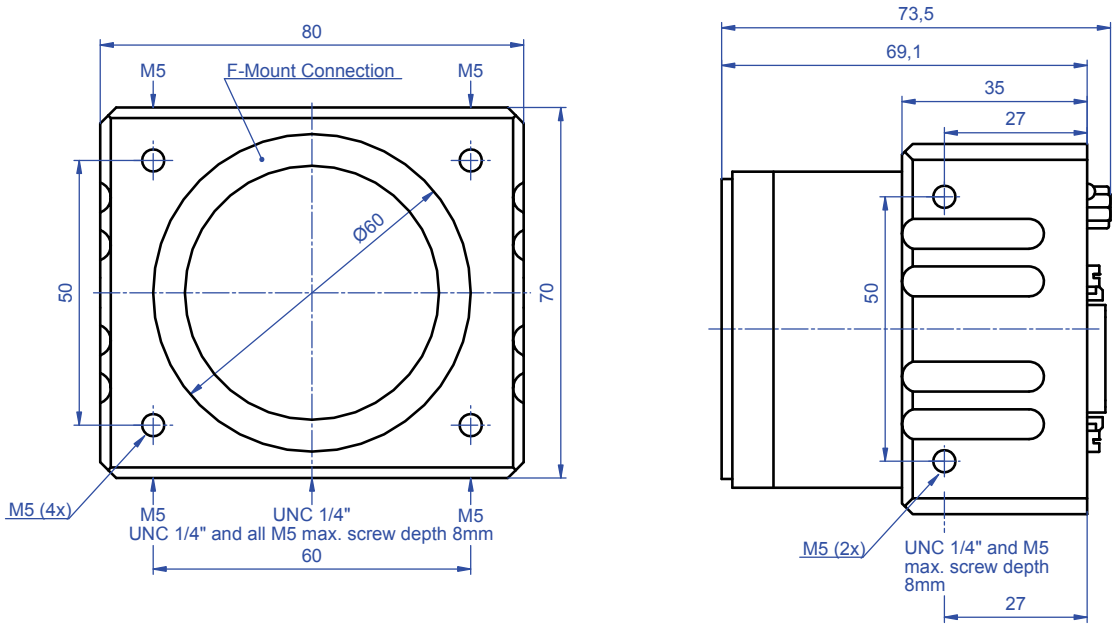


Figure 4: Camera dimensions: **Bonito CL-400B/C** F-Mount (front/side)

Back view of Bonito CL-400B/C C-/EF-Mount

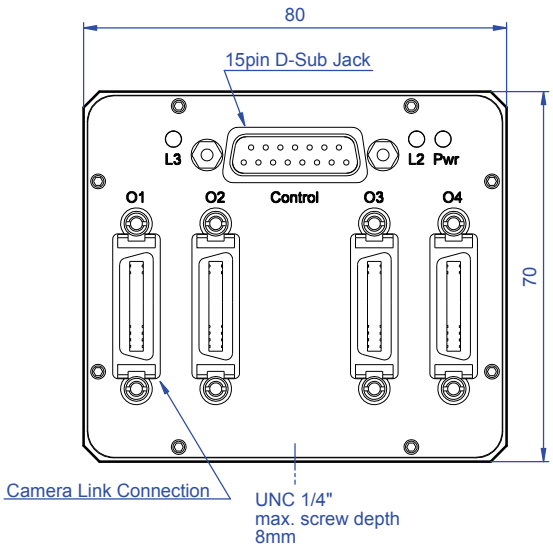


Figure 5: **Bonito CL-400B/C** C-/F-/EF-Mount (back)

LEDs	Color	Description
Pwr	Green	Power indicator
L2	Red	Camera operational indicator
L3	Red	Exposure indicator

Figure 6: LEDs

Connectors	Description
Control	12 V DC power supply, RS-232, optocoupler inputs and outputs
O1	Camera Link channel A (left) medium/full
O2	Camera Link channel A (left) base
O3	Camera Link channel B (right) medium/full
O4	Camera Link channel B (right) base

Figure 7: Connectors

Back view of Bonito CL-400B/C C-/EF-/F-Mount 200fps

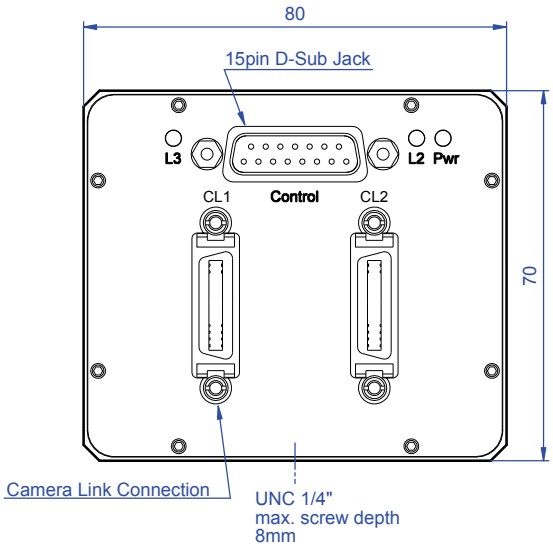


Figure 8: **Bonito CL-400B/C** C-/EF-/F-Mount 200fps (back)

LEDs	Color	Description
Pwr	Green	Power indicator
L2	Red	Camera operational indicator
L3	Red	Exposure indicator

Figure 9: LEDs

Connectors	Description
Control	12 V DC power supply, RS-232, optocoupler inputs and outputs
CL1	Camera Link Base
CL2	Camera Link Medium/Full

Figure 10: Connectors

Camera interfaces

This chapter gives you information on the control junction, inputs and outputs and trigger features.

www

For accessories like cables or power supply see:
http://www.alliedvisiontec.com/emea/products/accessories

Go to Camera Link section.

Requirements and serial I/O

Frame grabber requirements

Special care has to be taken in selecting the Camera Link frame grabbers. They should be able to process the 10 taps of each Bonito channel at 80 MHz clock frequency, which leads to a mean data rate of approx. 2 x 737 MiB/s (= 2 x 773 MB/s) net and a burst rate of up to 2 x 763 MiB/s (= 2 x 800 MB/s) net.

Camera configuration files for several frame grabbers are available from AVT GmbH on request.

Note

For more information on frame grabbers see manuals from frame grabber manufacturer.

PC Hardware requirements

A PC with high performance PCI Express (PCIe) system architecture is needed to cope with the high data rates. At least one free PCIe x4/x8/x16 slot is needed per frame grabber, depending on the specific frame grabber requirements.

Generally a short PCIe card may be plugged into a longer PCIe slot (e.g. a PCIe x4 frame grabber into a PCIe x16 slot). Often the main board manufacturers do not connect all lanes of a physical slot to the chipset. So ensure that at least the number of lanes which is needed by the frame grabber is electrically connected in the slot. Refer to the reference manual of the main board for details.

Currently we recommend main boards with Intel X58 chipset or better specification regarding the PCIe architecture.

Camera link cable length

The maximum Camera Link cable length for the Bonito is about 7 m, depending on the cable quality and the frame grabber.

Accessories

The Bonito needs a DC power supply with 12 V at an average current of 0.35 A (max. 0.4 A). The camera is delivered with suitable power supply without power cord.

The Bonito is available with C-Mount, F-Mount or EF-Mount lens adapter. Please consider the CMOS sensor size for lens selection. The lens should fully illuminate an area of ≥ 16 mm x 12 mm (ø 20 mm, type 4/3).

The software depends on the frame grabber. A software development kit (SDK) and a demo software for first live preview is usually provided by the frame grabber manufacturer.

Serial I/O

To configure the Bonito camera, an asynchronous serial command interface is provided. By default this command interface is internally routed via the Camera Link connector 02 (SerTC, SerTFG) or CL1 (**Bonito CL-400B/C 200fps**), but the RS232 signals at the 15-pin D-SUB control connector may also be used.

AVT provides the software **DeviceConfig** which can control the camera via standard PC RS232 COM ports and since version 1.2.1 also via the serial interface of the frame grabber. The latter needs a DLL provided by the frame grabber's manufacturer (clser*.dll).

www

For more information on **DeviceConfig** see

http://www.alliedvisiontec.com/emea/products/software/windows/deviceconfig.html

Note

For more information about serial communication via Camera Link please refer to the documentation of the particular frame grabber.

By default the serial interface uses the following parameters:

- 115200 Baud
- 8 data bits
- 1 stop bit
- No parity
- No handshake

The baud rate is factory-set to 115200 but can also be configured to other values: for more information see Chapter Baud rate (s) on page 53.

In all command examples the characters sent to the camera are represented in **`Bold Courier Font`** and the camera's answer in `Plain Courier Font`.

At power-up the camera loads the stored parameter configuration from its non-volatile memory and sends a start message after successful initialization to all activated serial interfaces.

This message is e.g. similar to the following:

```
Bonito CL / CMC-4000 CMOS High-Speed Camera
Version: CMC.040.xx.yy
>
```

The command prompt character > signals that the camera is ready to receive and process the next command. Each command consists of a command letter, followed by an equality sign and a parameter value in hexadecimal number representation. The command letter is case sensitive. Hexadecimal values are always upper case and are 1 to 8 hex digits long. The command is activated by a carriage return ([CR], ASCII character number 0x0D). Serial communication operates in echo mode by default. This means that each character received by the camera is echoed back to the sender.

Thus all serial commands (exceptions: **V**, **Y**, **a**, **?**) have the following general syntax:

>**A=wxyz [CR]**

Sign	Description
A	Command or parameter letter (observe upper and lower case printing!)
=	Equality sign (0x3D)
wxyz	1-8 digits long value in hexadecimal number representation (capital letters)
[CR]	Carriage Return (0x0D)
[LF]	Line Feed (0x0A)

Table 4: Syntax of serial commands

The following example sets the exposure time to 1000 = 0x3E8 time units:

1. The user sends the six characters
   E=3E8 [CR]
2. The camera answers with nine characters (echo followed by new prompt)
   E=3E8[CR][CR][LF]>
3. A terminal program without local echo displays
   E=3E8
   >

The command prompt character > always shows that the execution of the command has finished and the camera is ready for the next command. If any error occurred, somewhere previous to the prompt character a question mark character ? is sent.

To query a parameter value, just send the corresponding command letter followed by the equality sign and a question mark character:

```
>s=?[CR]
```

If the intended action does not need any parameter it is also sufficient in most cases – as a shortcut – to send the command letter only, directly followed by [CR].

At the beginning of a command sequence it is good practice to check the serial communication by sending just a [CR] to the camera and verify that the command prompt > is returned.

Note

There is an input buffer holding a few characters but no hardware handshake. Thus a sequence of commands should not be sent to the camera without awaiting the intermediate input prompts. This is especially important for serial command processing through user-developed software routines. Otherwise the camera's serial input buffer may overflow.

Camera I/O connector pin assignment (15-pin D-Sub jack)

This connector is intended for supplying power as well as external input/output signals.

Pin	Signal	Direction	Level	Description	RS232 9-pin D-SUB
1	External Power		+12 V DC (+5%, –10%), 0.35 A (4.2 W), max. 0.36 A	Power supply	
2					
3	External GND				5 (GND)
4					
5	Reserve				
6	Sync	Out	RS232	Synchronization signal	
7	RXD	In	RS232		3 (TXD)
8	TXD	Out	RS232	Serial control	2 (RXD)
9	Reserve				
10	Trigger input	-	Optocoupler input, 5 ... 12 V, 15 mA max.	External trigger signal	
11		+			
12	Exposure output	-	Optocoupler output, open collector, 30 V, 150 mW max.	Active exposure signal	
13		+			
14	Reserve				
15	Reserve				

Figure 11: Camera I/O connector pin assignment

Power supply (pin 1-4)

The camera requires 12 V DC (+5%, -10%) at a continuous maximum of 0.4 A.

We recommend to use respectively both pins for power supply (1–2 and 3–4).

Synchronization output (pin 6)

Note

Only cameras with firmware CMC.040.01.07 or newer support this feature.

If you use a camera with an older firmware version: don't connect pin 6.

Use this signal for the following:

- Synchronize external devices to the effective exposure of Bonito. Examples of external devices: flash lights or timer circuits.
- Reduce the timing jitter of start and end point of exposure. Several modes are available: for more information see Chapter Synchronization output (J) on page 39

The output is a RS232 compatible driver, signaling at +/- 6 V levels typically. The output delivers a reliable, low-jitter transmission, even over relatively long cable runs. The driver adds a delay of 0.75 µs typically at rising or falling edge.

Caution

Do not directly connect this output to a TTL or CMOS logic input.

Input may be destroyed, because output delivers several 10 mA at voltage levels - 6 V ... +6 V. These voltages may exceed the absolute limits of the input.

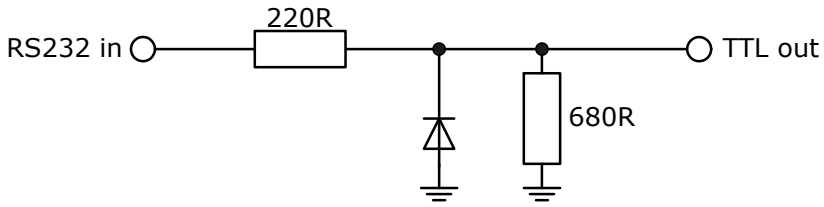


Figure 12: Example conversion circuit from +/- 6 V RS232 output to 5 V TTL input

Serial interface (pin 7-8)

By use of the serial interface at pin 7 and 8 the camera can be controlled externally via an RS232 COM Port. A simple terminal program (e.g. HyperTerminal) is sufficient for manually controlling the camera. Please note that operating this serial interface and the available port(s) via Camera Link concurrently may lead to unexpected results. Both interfaces share the same receive buffer and thus the characters of simultaneously sent commands may be randomly mixed up. For more information on general command syntax: see Chapter Serial I/O on page 20.

Trigger input (pin 10-11)

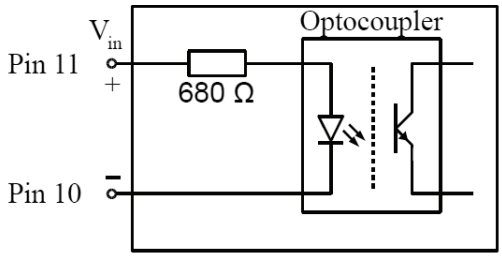


Figure 13: Trigger input diagram

The current through the optocoupler's LED should be in the range of 5 mA to 15 mA. This is the case if 5.0 V ≤ V_{in} ≤ 12 V.

Note If you use higher voltages, you have to connect externally an additional current limiting resistor.

A rising edge at this optocoupler input starts the exposure. It depends on the trigger input selection T and the current trigger mode M whether this input is enabled and how it controls the exposure time.

The optocoupler adds a typical delay of about 0.1 µs to the externally applied signal.

For more information on the various trigger and exposure modes: see Chapter Exposure control mode (M) on page 40.

Exposure output (pin 12-13)

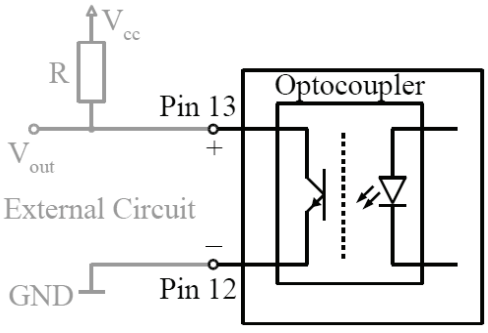


Figure 14: Exposure output

This is an open collector optocoupler output. The transistor is conductive during the active exposure time of the image sensor.

The power dissipation through the optocoupler's transistor must not exceed 150 mW.

A typical value for the external pull-up resistor is R = 4700 Ω. This ensures risk-free operation to the upper Vcc limit

Note The optocoupler adds an intrinsic delay to the signal.

Note This output is not recommended for new system designs.

Use the synchronization output feature instead: see Chapter Synchronization output (pin 6) on page 24.

The start of exposure edge (falling edge at V_{out}) is delayed for about 3 µs typically, the end of exposure edge for about 20 – 50 µs. Latter is mainly caused by the storage time of the photo transistor and is strongly depending on the external pull-up resistor value R. To let safely toggle the output between high and low state please use exposure times above 10 µs and also observe a gap of 50 µs or more between two exposures. Faster rates may also work, but should be tested individually. Consequently, in the default continuous mode (M=0) the output does not toggle because the inter-exposure gap is too short.

Active exposure is also displayed by the L3 indicator at the camera's back side.

Reserve I/O (pin 5, 9 and 14-15)

Note The pins 5, 9, 14 and 15 are reserved for future use. Do not connect. Currently they have no function, but this may change.

Camera Link interface (01-04 or CL1, CL2)

Camera Link is an interface for the transmission of digital video data. The standard defines data transfer on a physical base and determines connectors, cables and components for transmission and reception. Three different configurations (base, medium and full) are available, distinguished by the number of transmitter–receiver pairs (one, two or three respectively). While the base configuration is able to operate with one cable, for the medium and the full configuration two cables between camera and grabber are necessary.

Each transmitter–receiver channel implements the so called *Channel Link* technology. One Channel Link transmitter serializes 28 parallel data bits in a ratio of 7:1 and transfers them via five differential signal pairs (four data pairs plus one for the clock). By using the LVDS (Low Voltage Differential Signaling) standard, net parallel clock rates up to 85 MHz (up to 595 Mbit/s on the wire pairs) can be achieved.

The Camera Link standard also defines further non-serialized signals. There are four direct camera control lines (CC1 – CC4) from frame grabber to the camera, as well as a bi-directional asynchronous serial communication channel, all of them transmitted using the LVDS standard.

Due to the high bandwidth requirements the Bonito makes use of an extension to the Camera Link Full standard.

Camera Link Full defines 8 ports with 8 bits each. Thus it has a payload of 64 bits which – including synchronization signals – only occupy 76 of the 3 x 28 = 84 available transmitter bits. By incorporating the unused bits and some redundant synchronization signals, it is possible to transmit 10 x 8 = 80 bits net. This is also known as Camera Link 10-tap standard with 80 bits.

One Camera Link 80-bit channel provides enough bandwidth to achieve nearly 200 frames per second at four megapixels per frame. To reach the 400 frames per second the Bonito uses two Camera Link 80-bit channels in parallel.

Camera link connectors and 10-tap pin assignment

The Bonito implements two Camera Link 80-bit channels in 10-tap configuration grouped at the connector pairs 02/01 and 04/03 respectively. The **Bonito CL-400B/C 200fps** cameras implement only one Camera Link 80-bit channel at the connector pair CL1/CL2.

Each channel delivers ten Camera Link ports labelled A–J. Every port has eight bits and is assigned to a corresponding sensor tap which outputs specific pixel columns of the image. Consequently, up to 2 x 10 = 20 simultaneous pixels are transferred to the frame grabber(s) in parallel per Camera Link clock cycle.

The following illustrations depict the bit and wire assignments at the Camera Link connectors:

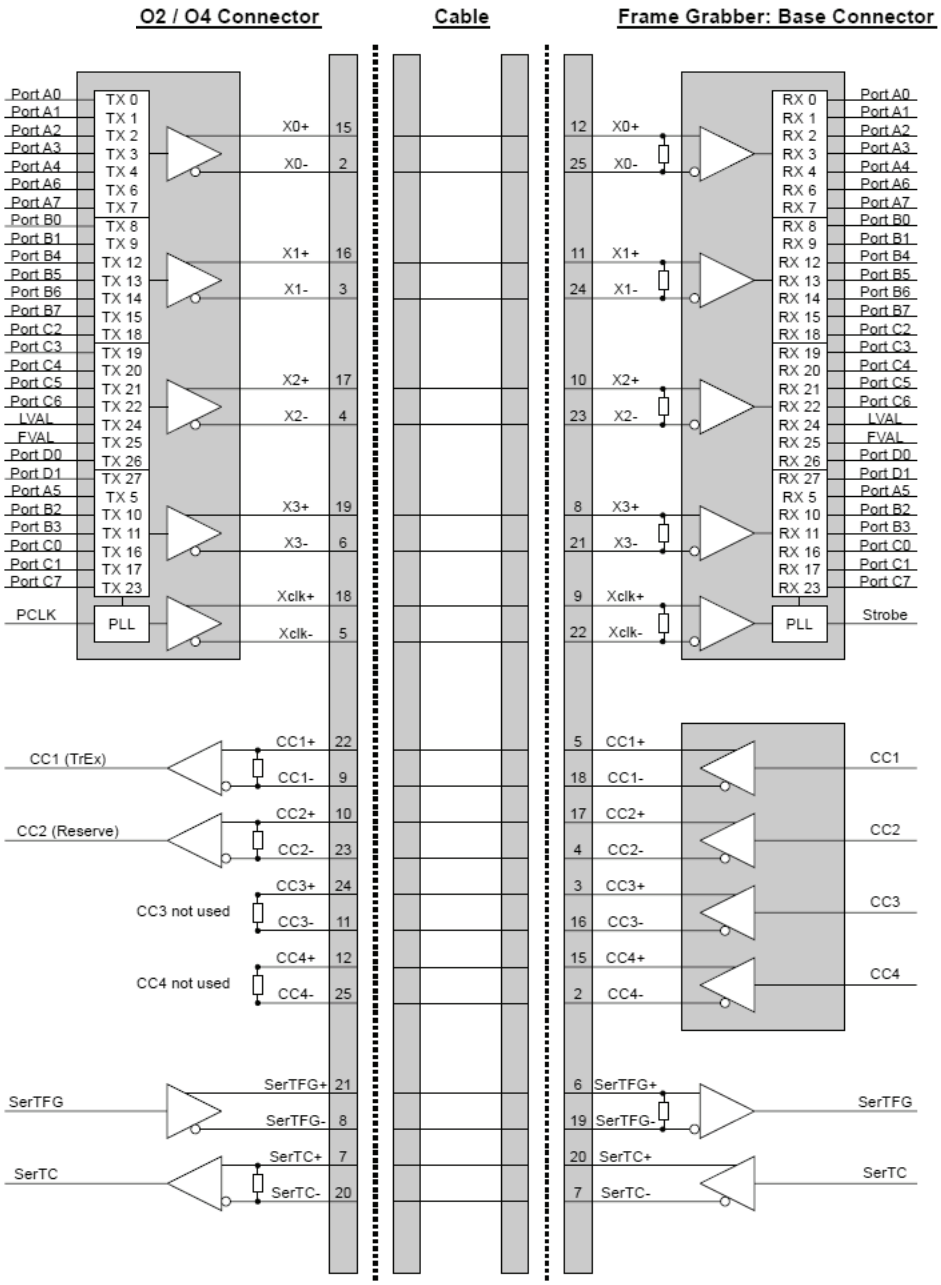


Figure 15: Camera link connector: 10-tap pin assignment (02/04 or CL1 connector)

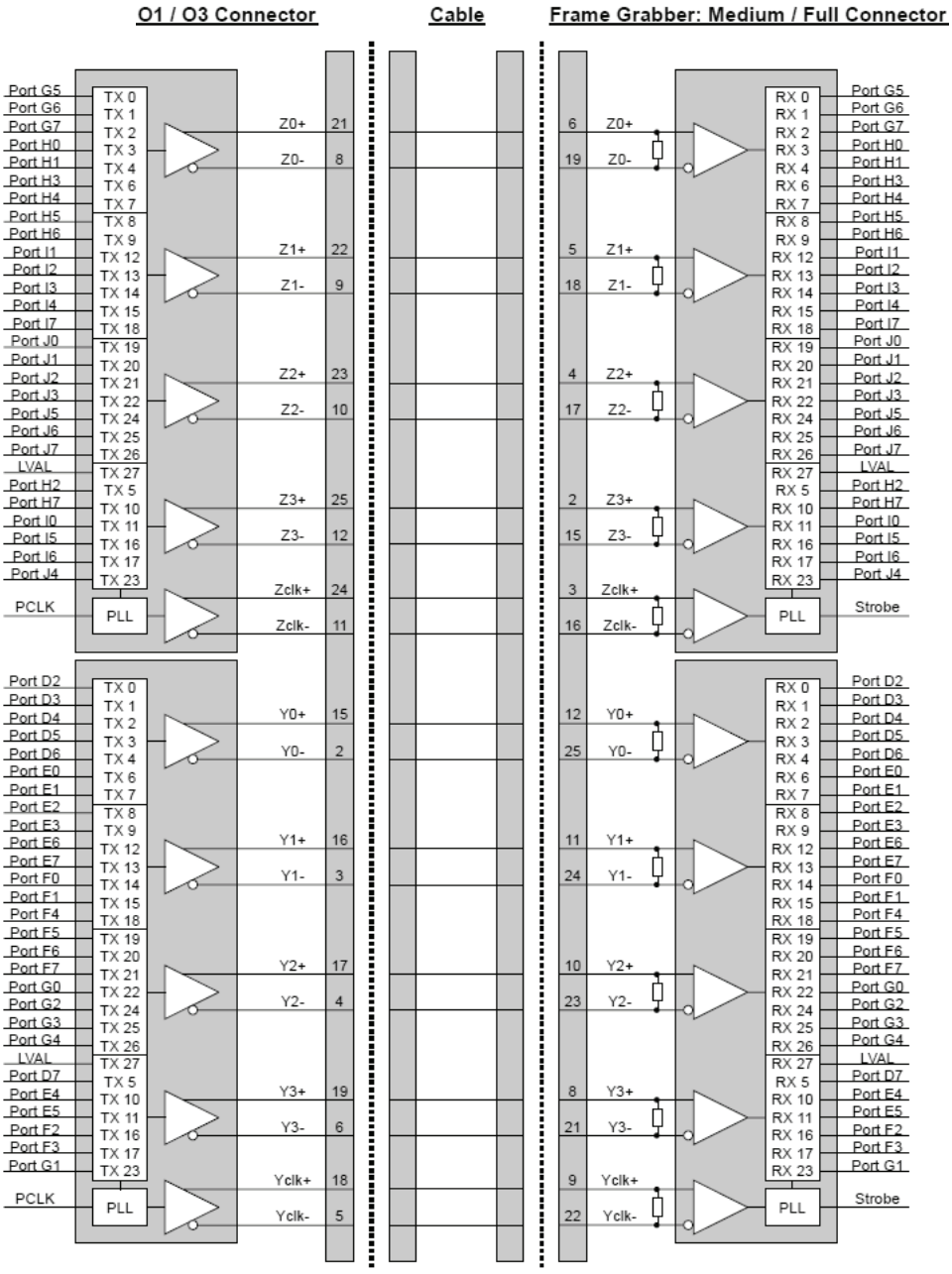


Figure 16: Camera link connector: 10-tap pin assignment (01/03 or CL2 connector)

Serial interface (SerTC, SerTFG)

The Camera Link connectors 02 and 04 (**Bonito CL-400B/C 200fps**: connector CL1 only) each provide the asynchronous serial control lines SerTC and SerTFG. This is the preferred communication channel to control the various camera functions. Both Camera Link serial interfaces (and also the third RS-232 interface at the 15-pin D-SUB connector) are virtually equal. They all use one global baud rate setting. They also share the same receive buffer. Output characters (including echo) are always sent to all activated serial ports. Thus the ports are not intended for concurrent activity, although it might be possible under particular circumstances.

However, the serial ports at 02 and 04 (or at CL1) may be deactivated.

Note

The **Bonito CL-400B/C 200fps** cameras provide only one Camera Link channel. Thus the serial interface via Camera Link is only available at the CL1 connector.

Note

- For more information on serial interface configuration: see Chapter Baud rate (s) on page 53.
- Consult the documentation of the frame grabber for more information on how to operate its integrated serial ports.

Trigger inputs (CC1)

The two Camera Link connectors 02 and 04 (or connector CL1) each provide a camera control signal CC1. A rising edge at either input may start an exposure. But it depends on the trigger input selection T and the current trigger mode M which of the both CC1 inputs is enabled and how it controls the exposure time.

Note

The **Bonito CL-400B/C 200fps** cameras provide only one Camera Link channel. Thus the serial interface via Camera Link is only available at the CL1 connector.

Note

For more information on the various trigger and exposure modes: see Chapter Exposure control mode (M) on page 40.

Reserve control input (CC2)

The camera control signals CC2 at the Camera Link connectors O2 and O4 (or connector CL1) are reserved for future use.

Pixel order

Each frame in single channel mode (S=0, max. 193 full frames per second) is transmitted from top left to bottom right, line per line. The diagram below shows how the image is reconstructed from the ten Camera Link taps A – J.

Because every tap directly corresponds to a Camera Link port, the port labels are reused as tap labels here. Each Camera Link clock cycle transmits one block of ten pixels. Please note that the number of lines may vary depending on the value of parameter N.

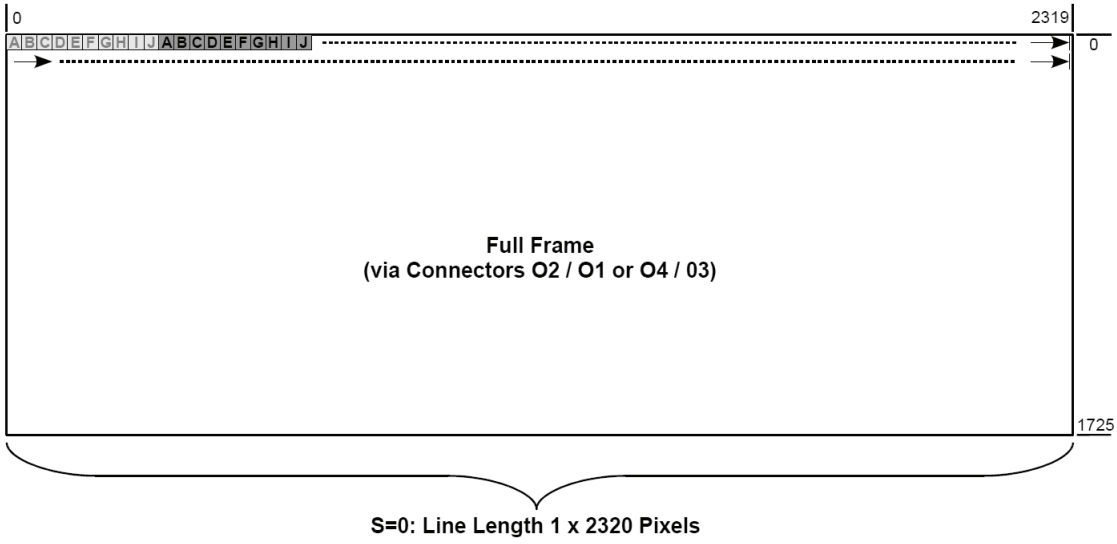


Figure 17: Pixel order: full frame

In the high speed dual channel modes (S=1 or S=3, max. 386 full frames per second) the image is split up vertically into two equal sized halves. Each half uses its own Camera Link channel and the pixel data travels over the corresponding connector pair.

Note This mode is not available for the **Bonito CL-400B/C 200fps** cameras.

From the host's point of view the Bonito basically behaves like two cameras with half of the possible image width. Thus the host computer receives two images at the same time which are reconstructed in the order shown below. It is the duty of the system designer to allow for assembly of the two halves if the application demands it.

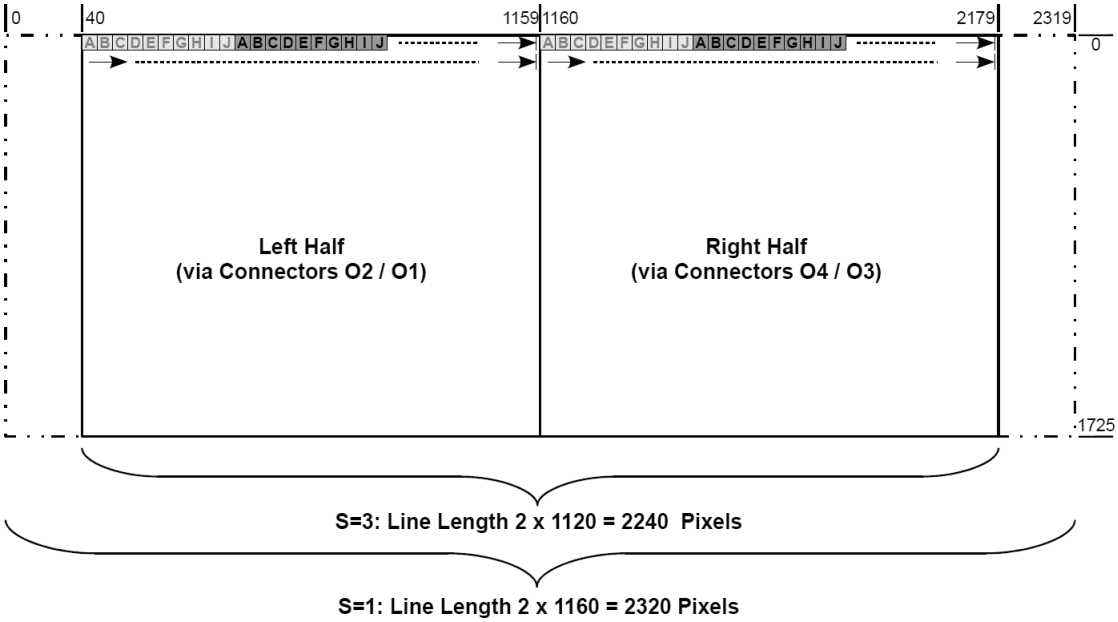

0
40
1159
1160
2179
2319
0
A B C D E F G H I J A B C D E F G H I J
A B C D E F G H I J A B C D E F G H I J
Left Half
(via Connectors O2 / O1)
Right Half
(via Connectors O4 / O3)
1725
S=3: Line Length 2 x 1120 = 2240 Pixels
S=1: Line Length 2 x 1160 = 2320 Pixels

Figure 18: Pixel order: half frame

Timing (FVAL, LVAL, PCLK)

The Camera Link pixel clock frequency of the Bonito is 80 MHz.

The 10-tap configuration transfers 10 pixels per clock cycle at once (or 20 per clock cycle in the dual-channel mode). The synchronisation signals LVAL and FVAL are used to designate valid data output.

Following charts illustrate the timing in continuous mode (**M=0**). Please note that the frame gap may vary in other trigger modes. Additionally the number of active lines per frame can be configured by the user (parameter **N**).

Camera Link timing for single channel mode (**S=0**):

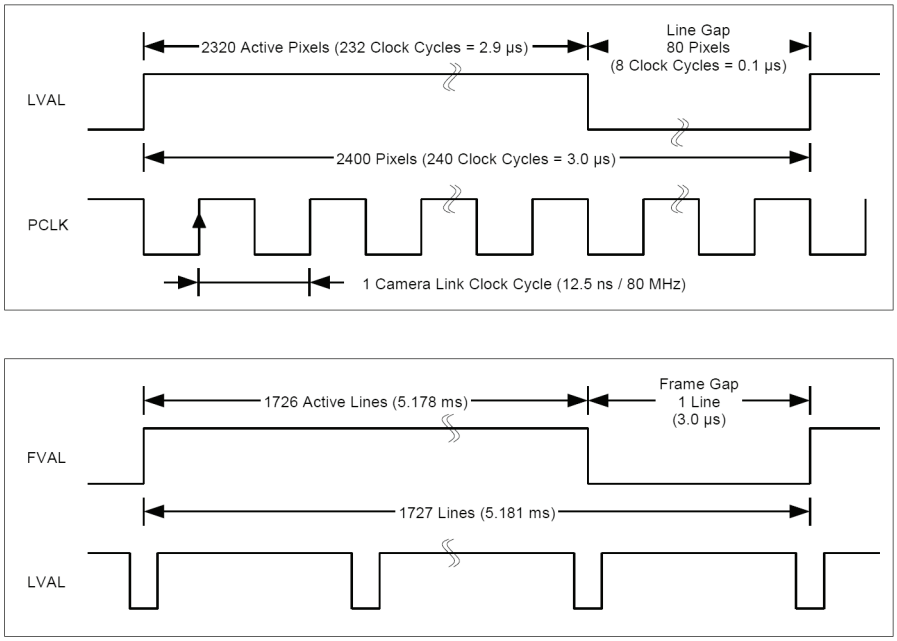


Figure 19: Timing single channel

Camera Link timing for dual channel mode (full line length, S=1, **not** for Bonito CL-400B/C 200fps):

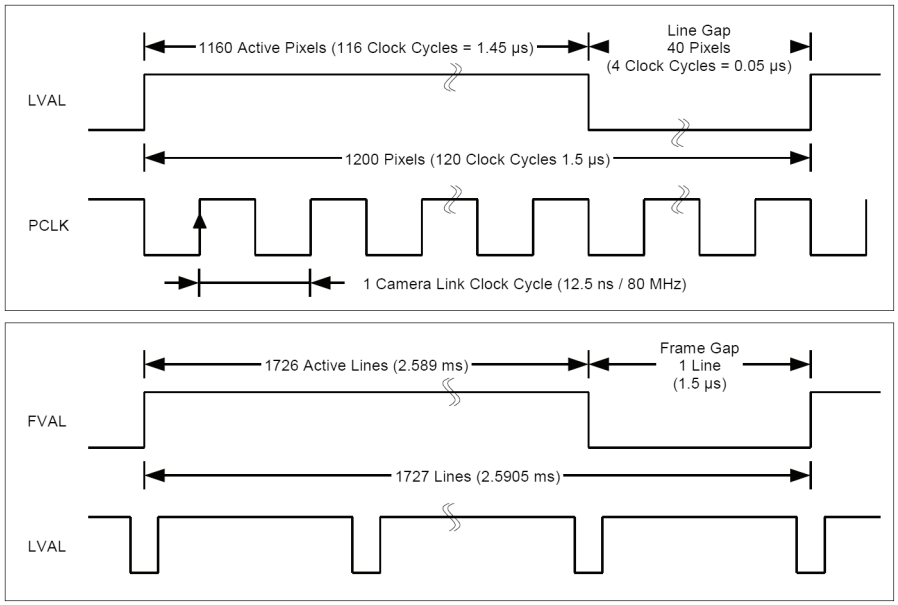


Figure 20: Timing dual channel, full line length

Camera Link timing for dual channel mode (compatibility mode with reduced line length, S=3, **not** for Bonito CL-400B/C 200fps):

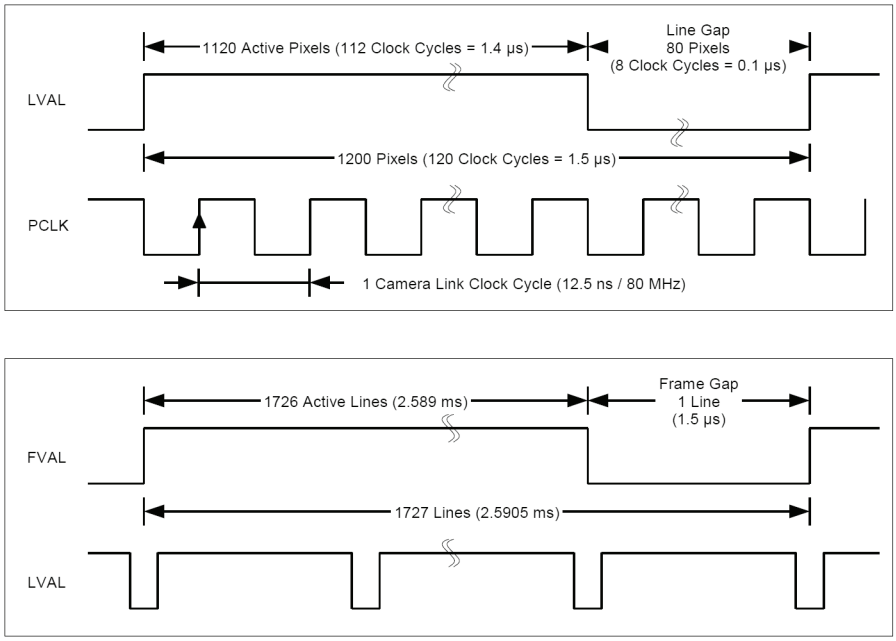


Figure 21: Timing dual channel, reduced line length

Parameters and Commands

This section explains the basic Bonito configuration parameters and general commands available to the user. Parameters and commands are communicated using the camera's serial interface.

Note For more information see Chapter Serial I/O on page 20.

Primary starting address (A)

The parameter **A** defines which line of the image sensor is the first line of the output image. The sensor's first (topmost) line has the address **A=0**, the last line has the address **A=6BD**. The value of **A** in conjunction with **N** and **I** is used to create a region of interest (ROI1). By default it is set to **A=0**.

Following sketch illustrates the various ROI parameters from the sensor's point of view:

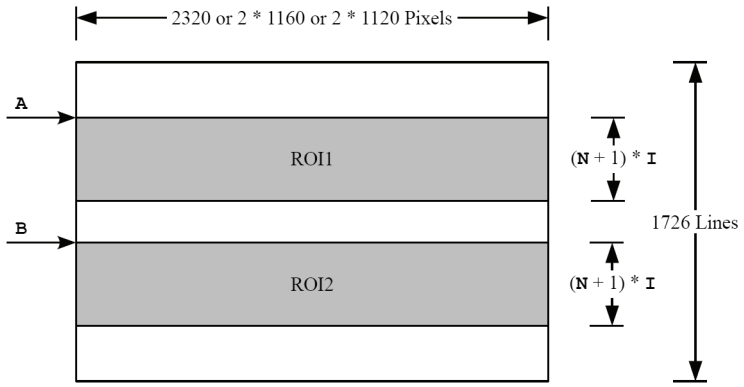


Figure 22: ROI parameters

Secondary starting address (B)

Note

For more information on double ROI mode see Chapter Double region of interest mode (D) on page 37.

If the double ROI mode is active, **B** defines which line of the image sensor is the first line of the second half of the output image. The sensor's first (topmost) line has the address **B=0**, the last line has the address **B=6BD**. The value of B in conjunction with N and I is used to create the secondary region of interest (ROI2).

Note

Each image sensor line can only be read once per exposure. Thus two ROIs are only possible as long as they do not share the same line addresses.

Fixed Pattern Noise (FPN) Correction (C)

The **Bonito** camera provides an FPN correction to improve image quality. Correction data has to be recorded under low-light conditions. For best correction quality new correction data should be acquired from time to time.

To acquire new FPN correction data follow this sequence:

- Try to eliminate bright light sources, e.g. switch them off if possible. For best correction quality, close the iris or use a lens cover.
- Ensure that the camera continuously outputs images at a constant frame rate, e.g. using the continuous mode:

  >M=0[CR]

  >
- Send the following serial command to record and apply new correction data. The camera answers with a new prompt sign if the command has successfully completed. The execution lasts for the duration of some images.

  >C=1[CR]

  >

Note

The correction data is volatile. So this command should be executed at least once after switching-on for best performance.

Double region of interest mode (D)

In double ROI mode (**D=1**) the camera outputs two equally sized regions of interest. Both ROIs share the parameters **N** and **I** and are output as two halves of one image. The top half contains the lines of the primary ROI (ROI1), the bottom half the lines of the secondary ROI (ROI2) accordingly.

The starting line address for ROI1 is configured using the parameter **A**.

Parameter **B** controls the starting line address of ROI2. Each ROI has the height of (**N** + 1) lines, thus the resulting image has (**N** + 1) * 2 lines.

Exposure time (E)

The exposure time is a 32-bit value. Its time resolution depends on the prescaler value **K** and is 3 µs by default. See Chapter Timer prescaler value (K) on page 39.

Technically the value range is 32 bit, whereas the useful exposure times should be up to ~ 1 second.

Note

The exposure time control using this value is only active if the trigger mode is set to **M=2** or **M=3**.

Frame duration (F)

The frame duration is a 32-bit value. Its time resolution depends on the prescaler value K and is 3 µs by default.

Note

The frame duration control using this value is only active if the trigger mode **M** is set accordingly.

See Chapter Exposure control mode (M) on page 40.

Digital gain (G)

The digital gain setting controls the shifting of the pixel bits. It selects, which eight of the ten digitizer bits are output to Camera Link. Overflow is represented by saturation to maximum.

Setting	Gain
G=0	1x
G=1	2x
G=2	4x

Table 5: Digital gain setting

Line address increment (I)

The line address increment value **I** is added to the current address at the end of each line read out from the sensor. Setting values > 1 skip lines accordingly. In conjunction with a reduced **N** this is useful to gain higher frame rates without diminishing the field of view (also known as sub-sampling). Valid values range from **I=1** to **I=FF**. The default is **I=1**.

Synchronization output (J)

Use parameter **J** to configure output on pin 6 of the camera control connector.

Setting	Output signal
J=0	Effective sensor exposure
J=1	Charge transfer pulse Active for one line duration at the end of exposure. End of this pulse marks the end of exposure and at the same time start of sensor readout. In PIV mode: this pulse occurs at the exposure end of only the first image of each PIV pair. For more information see Chapter Exposure control mode (M) on page 40.
J=2	Effective sensor readout
J=3	Exposure phase Contrary to J=0 this setting shows the exposure phase of the internal state machine and not the effective exposure of the sensor. This allows to synchronize external devices even if the sensor is in permanent exposure mode. For more details see Chapter Exposure control mode (M) on page 40.
J=8	Same as J=0, but with inverted logic on sync output
J=9	Same as J=1, but with inverted logic on sync output
J=A	Same as J=2, but with inverted logic on sync output
J=B	Same as J=3, but with inverted logic on sync output

Table 6: Synchronization output

Timer prescaler value (K)

A basic timer clock frequency of 56 MHz is divided by the prescaler value (**K** + 1) to generate the time base for exposure time **E** and frame duration **F**. This parameter is 16-bit wide. Valid values range from **K=1** to **K=FFFF**.

An assignment of **K=37** (decimal: 55) leads to a timer resolution of (55 + 1) / 56 MHz = 1 µs, for example. Default is **K=A7**, which equals 3 µs.

Note

Use **exact multiples** of the current line duration to minimize exposure and frame-to-frame jitter.

Exposure control mode (M)

There are various modes available to control the exposure time and frame duration of the **Bonito CL-400B/C**. The exposure control is depending on some general timing parameters which are specified in the following table:

Parameter	Value
Line Duration (S=0)	t_L = 3 µs
Line Duration (S=1)	t_L = 1.5 µs
Line Duration (S=3)	t_L = 1.5 µs
Frame Output Time (D=0)	$t_F = (\mathbf{N} + 1) * t_L$
Frame Output Time (D=1)	$t_F = 2 * (\mathbf{N} + 1) * t_L$
Minimum Frame Duration	$t_{FDmin} = t_F + t_L$
Timer Resolution	$t_{TR} = (\mathbf{K} + 1) / 56$ MHz

Table 7: Exposure control parameters

Use parameter **M** to setup the exposure control mode. The bits of the parameter value are divided into three different sized bit groups e, p and f. Each bit group has a special function being independent of the other ones:

Bit group	Description
e	Exposure timing mode
p	PIV mode
f	Exposure feature mode

Table 8: Exposure control mode: bit groups

7	6	5	4	3	2	1	0
-	-	f	f	-	p	e	e
		rw	rw		rw	rw	rw

Table 9: Exposure control mode: bit field order

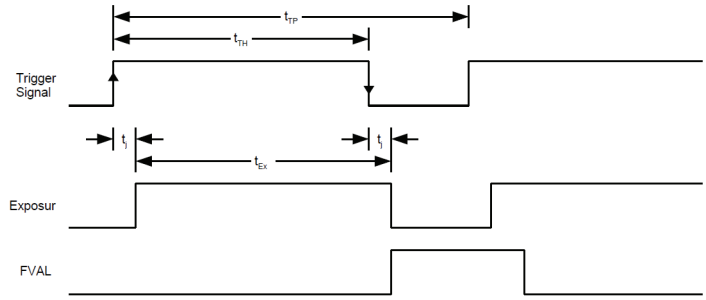
Bit group	Value	Function
e	0	**Continuous mode** The camera outputs images as fast as possible in a free running mode. The gap between two images is only one line, thus the total frame duration takes t_{FDmin}. The exposure time is nearly equal to this inherent minimal frame duration.
e	1	**Image on demand mode (IOD)** The exposure is directly controlled by an externally applied signal. Use parameter **T** to select the signal source. A rising edge at the corresponding input starts exposure synchronized to the line after the next. If the rising edge occurs during idle (the camera is not transmitting an image), the exposure starts with a constant delay of two line durations. The following falling edge stops exposure and starts output of the image synchronized to the next line. Due to the line jitter the next exposure should not start earlier than $t_{FDmin} + t_L$ after the previous start of exposure.  **Parameter** / **Value** Trigger Period: $t_{TP} > t_{FDmin} + t_L$ Trigger High Duration: $t_L < t_{TH} < t_{TP} - t_L$ Exposure Jitter: $0 < t_j < t_L$ Exposure Time: $t_{Exp} = t_{TH} \pm t_j$ Table 10: M=1 parameters

Table 13: Exposure control modes: Exposure timing mode (bit group: e)

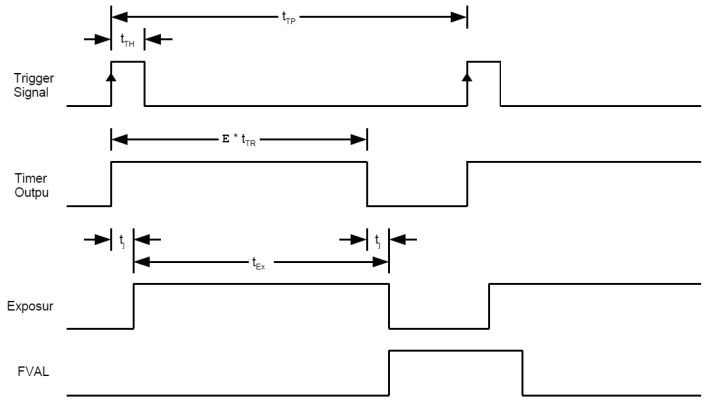
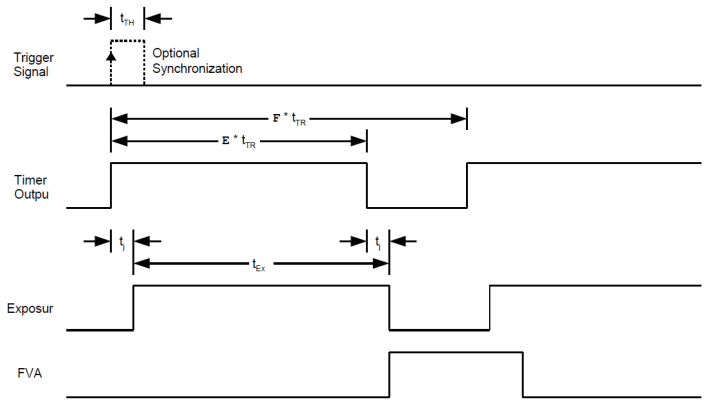
Bit group	Value	Function
e	2	**Image on demand mode (IOD) with exposure timer** The exposure time is controlled by the parameter **E**. Each rising edge of an externally applied signal starts one exposure. Use parameter **T** to select the signal source. A rising edge at the corresponding input starts exposure synchronized to the line after the next. If the rising edge occurs during idle (the camera is not transmitting an image), the exposure starts with a constant delay of two line durations. The next rising edge must not arrive earlier than $t_{FDmin} + t_L$ after the previous one.  **Parameter** / **Value** Trigger Period: $t_{TP} > \max(t_{FDmin}, E * t_{TR}) + t_L$ Trigger High Duration: $t_L < t_{TH} < t_{TP} - t_L$ Exposure Jitter: $0 < t_j < t_L$ Exposure Time: $t_{Exp} = E * t_{TR} \pm t_j$ Table 11: M=2 parameters

Table 13: Exposure control modes: Exposure timing mode (bit group: e)

Bit group	Value	Function
e	3	**Image on demand mode (IOD) with exposure timer and frame duration timer** This mode is also free-running (like M=0), but exposure time and frame duration is set using the parameters **E** and **F** accordingly. Furthermore the start of the exposure may optionally be synchronized to the rising edge of an externally applied synchronization pulse. Use parameter **T** to select the synchronization signal source. In case of synchronization event during exposure the current frame may be exposed abnormally.



Parameter	Value
Trigger High Duration (Sync Pulse)	$t_L < t_{TH} < F * t_{TR} - t_L$
Exposure Jitter	$0 < t_j < t_L$
Exposure Time	$t_{Exp} = E * t_{TR} \pm t_j$
Frame Duration	$F * t_{TR} \geq \max (t_{FDmin} + t_L , E * t_{TR} + t_L)$

Table 12: M=3 parameters

Table 13: Exposure control modes: Exposure timing mode (bit group: e)

Bit group	Value	Function
p	0	**PIV mode = Off**
p	1	**PIV mode = On** PIV means Particle Image Velocimetry. Exposure control is not available in this mode. The exposure is permanently active. Thus a synchronized strobe light source and eliminating other light sources is mandatory. The frame rate is controlled as usual using parameter F or external trigger, but note that the camera outputs two images per trigger event. The strobe light has to be synchronized to the image output of the camera. This can e.g. be done by an external timing generator which generates a pair of flash pulses positioned close to each trigger pulse to the camera. The exposure of the first image ends one line duration (t_L) after the rising edge of the incoming trigger signal. Thus the first light pulse should end a few 100 ns before t_L and the second light pulse should start a few 100 ns after t_L. The ideal position and length of this dark guard interval depends on the allowable crosstalk of the application and should be tested individually. If not in continuous mode the time between two rising trigger edges must exceed 1+2*((**N**+1)+1) line durations. The trigger high duration should be less than N+1 line durations, but at least 500 ns. Alternatively the synchronization of light sources can be implemented by using the corresponding output signal of the camera. For information on synchronization output see **J** in Chapter Synchronization output (J) on page 39.

Table 14: Exposure control modes: Exposure timing mode (bit group: p)

Bit group	Value	Function
f	0	**Standard mode**
f	1	**Enhanced full well (3T) mode** The full frame shutter is not available in this mode. Instead, the sensor operates in rolling shutter mode with an effective shutter time equaling the frame duration. Thus a synchronized strobe light is recommended. Consequently any exposure time setting, controlled by Parameter **E** or by external signal, is ignored. The light should flash between two image readout operations, which may be the duration of one line at highest possible frame rate. Decrease the frame rate accordingly, if longer exposure times are needed. Use the sync output (RS232 driver at pin 6) for synchronization, if needed.
f	2	**Permanent exposure mode** Use this mode to maximize the exposure time. If activated, the exposure time equals the frame duration. Consequently any exposure time setting, controlled by parameter **E** or by external signal, is ignored.
f	3	**Reserved**

Table 15: Exposure control modes: Exposure timing mode (bit group: f)

Number of lines (N)

The number of lines per frame is controlled with **N**. The actual line count is **N**+1, thus the default of **N=6BD** results into 1726 output lines. Valid values range from **N=0** to **N=6BD**. If the double ROI mode is active (**D=1**) the actual line count is doubled: (**N** + 1) * 2.

Note

- Consider this in minimum frame duration calculations for the image on demand (IOD) mode.
- For more information about calculation of the minimum frame duration and dependent IOD mode timing constraints, see Chapter Exposure control mode (M) on page 40.
- See also the other ROI parameters **A**, **B**, **D** and **I**.

Timing examples for parameter settings **M=0**, **S=0** [t_L = 3 µs], **D=0**:

Setting	No. of lines	Minimum frame duration t_{FDmin}	Frame rate/fps
N=6BD	1726	5.181 ms	193.01
N=681	1666	5.001 ms	199.96
N=14B	332	0.999 ms	1001.0
N=1F	32	0.099 ms	10101
N=0	1	0.006 ms	166667

Table 16: Timing examples (M=0, S=0, D=0)

Timing examples for parameter settings **M=0**, **S=1** [t_L = 1.5 µs], **D=0** (**not** for Bonito CL-400B/C 200fps cameras):

Setting	No. of lines	Minimum frame duration t_{FDmin}	Frame rate/fps
N=6BD	1726	2.5905 ms	386.03
N=681	1666	2.5005 ms	399.92
N=14B	332	0.4995 ms	2002.0
N=1F	32	0.0495 ms	20202
N=0	1	0.0030 ms	333333

Table 17: Timing examples (M=0, S=0, D=0)

Camera Link output mode setting (S)

The parameter **S** controls how the camera outputs pixel data to the Camera Link interface.

- For more information about how the resulting image is reconstructed in the various modes, see Chapter Pixel order on page 31.
- For more information about pixel output timing, see Chapter Timing (FVAL, LVAL, PCLK) on page 33.

Setting	Function
S=0	Default: **Single channel mode** (193 frames per second with line length of 2320 pixels) The camera utilizes one Camera Link 80-bit channel in 10-tap configuration. It allows only half of the maximum frame rate but also produces less noise in the image because the sensor clock frequency is reduced. The preferred Camera Link connector pair for this mode is the left channel 02 / 01, but the other pair (04 / 03) also outputs all pixel data. Please note that the CC signals and SerTC / SerTFG are handled separately per channel. Thus e. g. the trigger source selection (**T**) and serial port configuration (**s**) might need adjustments if 04 / 03 are used. The **Bonito CL-400B/C 200fps** provides only one channel at the connectors CL1/CL2.
S=1	**Dual channel mode** (**not** for Bonito CL-400B/C 200fps) (386 frames per second with line length of 2 x 1160 = 2320 pixels) The image is split vertically into a left and a right half. Thus each half has a horizontal size of 1160 pixels and is output separately via its own Camera Link 80-bit channel. The left half travels via the left Camera Link channel at the connectors 02 / 01 and the right half travels via 04 /03 respectively.
S=3	**Dual channel mode** (**not** for Bonito CL-400B/C 200fps) (386 frames per second with line length of 2 x 1120 = 2240 pixels) This mode basically is the same as **S=1**. For frame grabber compatibility reasons some pixel columns at the left and right side (of the full image) are dropped so that the line length of each half image is divisible by 16.
S=5	Same as mode 1, but with right image half via 02/01 and left image half via 04/03 (if available).

Table 18: Output mode setting (S)

Setting	Function
S=7	Same as mode 3, but with right image half via 02/01 and left image half via 04/03 (if available).
Others	Reserved for future use.

Table 18: Output mode setting (S)

Trigger source selection (T)

This parameter selects the signal source for triggering and exposure control.

For more information about usage of the selected signals: see Chapter Exposure control mode (M) on page 40.

Setting	Function
T=0	No input selected.
T=2	Optocoupler OK1 at pins 10 and 11 of the control connector. **Note** This input adds additional delay to the signal. For more information: see Chapter Trigger input (pin 10-11) on page 25.
T=3	CC1 at the Camera Link connector 02 or CL1 (default).
T=4	CC1 at the Camera Link connector 04.
Others	Reserved for future use.

Table 19: Trigger source selection (T)

Metadata overlay and test image generator (U)

The Bonito can overlay the image's first pixels with some bytes of metadata, such as a hardware frame counter. The frame counter increments for each image read out from the sensor. This helps to increase system reliability by detecting missing frames on the host system. In dual channel mode (**S=1** or **S=3**) it can also be used to join the two related image halves because they have the same counter value.

Furthermore, to test the Camera Link cabling and frame grabber operability, a test image generator is available. It forces the camera to output an almost fixed test image containing grey wedges, black and white stripes with various frequencies and edge markers.

Note

- The effective image size and also the frame rate depend on the corresponding camera settings such as e.g. **D**, **N** or **M**. Edge markers are only fully visible if all 1726 active lines are output.
- The digital gain setting **G** also applies to the test image, but the FPN correction **C** is temporary disabled.

Setting	Function
U=0	Normal image output.
U=1	Enable metadata overlay The overlay occupies the first (top left) 8 pixels of each frame. Metadata format for the left Camera Link channel (connectors 02/01 or CL1/CL2): • Pixel offset 0–3 (4 bytes): constant ASCII characters *CM4L* • Pixel offset 4–7 (4 bytes): 32-bit frame counter, LSB first (Intel format) Metadata format for the right Camera Link channel (connectors 04/03): • Pixel offset 0–3 (4 bytes): constant ASCII characters *CM4R* • Pixel offset 4–7 (4 bytes): 32-bit frame counter, LSB first (Intel format)
U=10	Enable test image generator. Full test image appears with **N=6BD**, **I=1**, **G=0** and **D=0**.
U=11	Enable metadata overlay and test image generator.
Others	Reserved for future use

Table 20: Trigger source selection (T)

Dark value offset (W)

This value is an 8-bit parameter which is added to the pixel data. This parameter adjusts the dark level and avoids clipping of pixels to black in low light situations. The eight bits are aligned to the lowest significant bit of the 10-bit raw pixel data from the sensor. Thus if the digital gain is not active (**G=0**), each increment of four increases the output grey level just for one count.

Version information (V)

The command **V** displays information about the camera model and firmware version.

```
>V
Bonito CMOS High-Speed Camera
Version: CMC.040.xx.yy
>
```

Save parameters (X)

Use the command **X=1** to store all parameter values into the embedded flash memory. After a re-start they are automatically restored.

Note

Acquired FPN correction data is not stored and is therefore lost after switch-off.

See Chapter Fixed Pattern Noise (FPN) Correction (C) on page 36.

Parameter summary (Y)

The command **Y** shows a summary of all current parameter value settings.

Reset to factory defaults (Z)

The command **Z=1** sets the camera into a factory default state. To save the new parameter configuration, the command **X=1** has to be executed afterwards.

The default settings are:

```
A=0000
B=0000
C=00
D=00
E=000006BE
F=000006BF
G=00
I=01
J=01
K=A7
M=00
N=06BD
S=00
T=03
U=00
W=18
s=2A
>
```

Note

The serial interfaces are not reinitialized by **Z=1**. Thus the baud rate does not change until re-start of the camera or explicitly writing a new value to the serial interface configuration parameter **s**.

Serial number (a)

The camera's serial number is stored as 16-bit value. Use the command **a** to read it.

Product variant code (b)

The product variant code is a 16-bit number unambiguously identifying the camera variant. Use command **b** to read it.

b	Article number	Camera Variant
0000	1064000	CMC-4000 / C-Mount
0001	1064001	CMC-4000 / F-Mount
0002	1064002	CMC-4000 / EF-Mount
0010	1064010	CMC-4000C / C-Mount
0011	1064011	CMC-4000C / F-Mount
0012	1064012	CMC-4000C / EF-Mount
4000	4064000	Bonito CL-400B
4001	4064001	Bonito CL-400B F-Mount
4002	4064002	Bonito CL-400B EF-Mount
4010	4064010	Bonito CL-400C
4011	4064011	Bonito CL-400C F-Mount
4012	4064012	Bonito CL-400C EF-Mount
4020	4064020	Bonito CL-400B 200fps
4021	4064021	Bonito CL-400B F-Mount 200fps
4022	4064022	Bonito CL-400B EF-Mount 200fps
4030	4064030	Bonito CL-400C 200fps
4031	4064031	Bonito CL-400C F-Mount 200fps
4032	4064032	Bonito CL-400C EF-Mount 200fps
FFFF	-	Unknown / test / prototype

Table 21: Product variant code (b)

Baud rate (s)

The Baud Rate of the serial interface is setup using parameter **s**.
The bits of the parameter value are divided into three different sized bit groups **a**, **e** and **x**.
Each bit group has a special function being independent of the other ones:

Bit group	Description
a	Controls the enable state of the serial ports.
e	Controls the echo mode.
x	Controls the baud rate of the serial port.

Table 22: Baud rate: bit groups

F	E	D	C	B	A	9	8	7	6	5	4	3	2	1	0
-	-	-	-	-	-	-	-	e	a	a	-	x	x	x	x
								rw	rw	rw		rw	rw	rw	rw

Table 23: Baud rate

Baud Rate (default setting 2A)		
Bit group	**Value**	**Explanation**
x	0	110 Baud*
	1	300 Baud*
	2	600 Baud*
	3	1200 Baud*
	4	2400 Baud*
	5	4800 Baud*
	6	9600 Baud
	7	19200 Baud
	8	38400 Baud
	9	57600 Baud
	A	115200 Baud

Table 24: Baud rates: Bit groups and values

Baud Rate (default setting 2A)		
a	00	RS232 via 15-pin D-SUB control connector only.
	01	Additionally activates second channel via Camera Link connector 02.
	10	Additionally activates second channel via Camera Link connector 04.
	11	Additionally activates second channel via Camera Link connector 02 and 04.
e	0	Each character received from the host is echoed back to it.
	1	No echo

Table 24: Baud rates: Bit groups and values

* These baud rates are not available via Camera Link.

Example 1 Factory default: s=2A

means: 115200 Baud, Each character received is echoed back, Additionally activates second channel via Camera Link connector 02.

Example 2 s=004A

means: 115 200 Baud, RS232 via 15-pin D_SUB, no echo

Show Help text (?)

The command **?** shows an embedded command reference text at the serial terminal. It lists a short description for each command available in the firmware.

Bayer filter mosaic pattern

The color variants of the Bonito are equipped with a Bayer filter mosaic on the image sensor, which is aligned to the top left corner of the sensor like shown in the following pattern:

G	R	G	R	...
B	G	B	G	...
G	R	G	R	...
B	G	B	G	...
...	...	...	...	...

Changing the output mode (parameter **`S`**) does not affect the pattern alignment in the output image. On the other hand modifying the ROI settings (**`A`**, **`B`**, **`D`**, **`I`**, **`N`**) may lead to misalignments. Please observe the consistent mapping of even and odd sensor rows to even and odd rows in the output image when changing the ROI settings.

Appendix

Command reference

This chapter describes the general command reference of the **Bonito CL-400B/C** firmware. It can be output to the camera's serial interface by sending the command **?=1**.

```
Bonito CL-400 and CMC-4000 Series Command Reference
===================================================================================
Referenced Firmware...: CMC.040.01.07
Document Version......: 06 / 02.02.2012

(C) Allied Vision Technologies GmbH


General Information
-------------------

Each command consists of a command letter, optionally followed by an equality
sign and a parameter value in hexadecimal number representation. The command
letter is case sensitive. Hexadecimal values are always upper case and are 1 to
8 digits long. The command is activated by sending a carriage return character
([CR], ASCII character number 0x0D). Serial communication operates in echo mode
by default. This means that each character received by the module is echoed
back to the PC.

Example (set Baudrate to 115200 Baud, RS-232 only):
s=A[CR]

After successful execution of the command, the command prompt character ">" is
output. If any error occurred, somewhere previous to the prompt a question
mark character "?" is displayed.

To query a parameter value, send the corresponding command letter followed by
the equality sign and a question mark character:
s=?[CR]

If the intended action does not need any parameter, it is also sufficient - as
a shortcut - to send the command letter only, directly followed by [CR].

At the beginning of a command sequence it is good practice to check the serial
communication by sending just a [CR] to the camera and verify that the command
prompt ">" is returned. There is an input buffer holding a few characters
but no hardware handshake. Thus a sequence of commands should not be send to
the camera without awaiting the intermediate input prompts. Otherwise the
camera's serial input buffer may overflow.


How to use Help
---------------

To see this help text type the following command:
?[CR]
```

```
Conventions
-----------

<p8>         : 8 bits long parameter value (1 to 2 Hex characters)
<p16>        : 16 bits long parameter value (1 to 4 Hex characters)
<p32>        : 32 bits long parameter value (1 to 8 Hex characters)
<aa**_bcbb>  : 8 bits long parameter (resulting in two hex chars)
               consisting of bit fields. The function of each bit field is
               described, like this:
                 "aa"    : Lower case letters label the bits of interest.
                 "**"    : Reserved, should be written as "0", read undefined.
                 "_"     : Separation character for readability.
                 "bcbb"  : Bit fields may have any length and can be split up.
(*)          : Some commands are only accessible in a special password protected
               service mode.


Command and Parameter Overview - Service Mode
---------------------------------------------

a=<p16>          : Set the serial number A and save it to flash. In user mode
                   read access to this value is available. (*)

b=<p16>          : Set the product variant code and save it to flash. In user
                   mode read access to this value is available. (*)

c=<p8>           : Configure the FPGA with data from the specified file
                   number. (*)

d=<p8>           : Delete the file with the specified file number. (*)

e=<p8>           : Erase the flash. (*)
                     e=0          : Erase used blocks only.
                     e=FF         : Erase all blocks.
                     Other Values: Reserved / undefined.

f=<p16>          : Write a data byte to an FPGA register. (*)
                     High Byte    : Data value to write, 0 if omitted.
                     Low Byte     : Address of the register.

g=<p16>          : Read data bytes from FPGA registers at specified
                   address. (*)
                     High Byte    : Number of sequential bytes to read. Set the
                                    most significant bit in order to reverse the
                                    byte output order. If high byte is omitted, a
                                    default count value of 1 is assumed.
                     Low Byte     : Base address to read from. On forward byte
                                    order the address is incremented until it
                                    reaches [base]+[count]-1. On reverse byte
                                    order the output starts at [base]+[count]-1
                                    and is decremented down to [base].

l=1              : List contents of the flash file directory. (*)

v=<p8>           : View contents of the specified file. (*)
```

```
z=1             : Reload parameters from file. (*)

O=<p8>          : File number of the file containing the FPGA configuration
                  data. (*)

P=1             : Upload a new FPGA configuration file via the serial
                  interface and store it in the flash memory. After issuing
                  <CR> a special transfer protocol is processed. A currently
                  existing file will be overwritten. (*)

Q=<p8>          : Upload a general file via the serial interface and store
                  it in the flash memory using the specified file number.
                  After issuing <CR> a special transfer protocol is processed.
                  A currently existing file will be overwritten. (*)


Command and Parameter Overview - User Mode (Lower Case)
-------------------------------------------------------

p=<p16>         : Internal system parameter. Change this setting only if you
                  know what you are doing!
                  <ssss_ssss_cccc_cccc>
                   \_______| \_______|
                           |         +---c: Camera Link clock phase. Modify
                           |                this byte value a few steps up or
                           |                down to optimize the phase of the
                           |                Camera Link clock. It may
                           |                eventually improve data
                           |                transmission reliability with
                           |                long cable runs in some cases.
                           +-------------s: Internal system parameter. Do not
                                            change this byte at all. To modify
                                            the other bitfield "c" please first
                                            read all bits of p=<p16> from the
                                            camera, modify only the bits of "c"
                                            and write back the complete value
                                            including the "s"-bits unchanged.

s=<p8>          : Configure the UART(s) for serial communications. Changes are
                  activated immediately.
                  <eaa*_bbbb>
                   |\|  \__|
                   | |     +---b: Baud rate of the main RS-232 UART available
                   | |            at the 15-pin D-SUB connector and the second
                   | |            channel UART via Camera Link. The second
                   | |            channel UART supports 9600 to 115200 Baud
                   | |            only (x). Both channels share the same
                   | |            receive buffer and output characters are
                   | |            always sent to both. Thus the two channels
                   | |            are not intended for completely concurrent
                   | |            use.
                   | |              0 -> 110 Baud.
                   | |              1 -> 300 Baud.
                   | |              2 -> 600 Baud.
                   | |              3 -> 1200 Baud.
                   | |              4 -> 2400 Baud.
                   | |              5 -> 4800 Baud.
                   | |              6 -> 9600 Baud. (x)
```

```
                  | |              7 -> 19200 Baud. (x)
                  | |              8 -> 38400 Baud. (x)
                  | |              9 -> 57600 Baud. (x)
                  | |              A -> 115200 Baud. (x)
                  | +---------a: Second channel UART port selection.
                  |              00 -> Second channel UART off.
                  |              01 -> Activate second channel via Camera
                  |                    Link connector O2 (or CL1).
                  |              10 -> Activate second channel via Camera
                  |                    Link connector O4 (if available).
                  |              11 -> Activate second channel via Camera
                  |                    Link connector O2 (or CL1) and O4.
                  +-----------e: Echo suppression.
                                 0 -> Each character received from the host
                                      is echoed back to it.
                                 1 -> No echo.
```

Command and Parameter Overview - User Mode (Upper Case)

A=<p16> : Start value for line address counter A. It sets the line address of the image's first line read out from the image sensor. After processing each line the address is incremented by the amount specified by I=<p8>. See N=<p16> for number of lines per image. Valid range 0...6BF (decimal: 0...1727).

B=<p16> : Start value for line address counter B. It sets the line address of the second ROI's first line read out from the image sensor. After processing each line the address is incremented by the amount specified by I=<p8>. See N=<p16> for number of lines per image. This parameter is only used in double ROI mode. Please see command D=<p8> for details. Range 0...6BF (decimal: 0...1727).

C=<p8> : Mode and control of the fixed pattern noise (FPN) correction. Please note that correction data is volatile and has to explicitly be acquired at least once after switching on the camera.

```
<****_**sm>
        ||
        |+-m: Mode of fixed pattern noise correction.
        |       0: No correction is applied.
        |       1: Acquire new fixed pattern noise correction
        |          data and apply it to the image. To
        |          successfully complete the procedure ensure
        |          continous image output by e.g. setting
        |          M=0. For optimum quality please totally
        |          darken the sensor during data acquisition.
        |          Avoiding bright light sources might also
        |          be sufficient, but a residual image may
        |          occur. Please note that saving the
        |          correction state with X=<p8> will activate
        |          the correction at start of the camera
        |          without correction data. This leads to an
        |          uncorrected image until new correction
        |          data has explicitly been reacquired.
```

```
                        +--s: Suppression of new data acquisition. This bit
                              is write-only and reads always 0. Write C=3 to
                              reactivate the fixed pattern noise correction
                              from the state C=0 without the correction data
                              being reacquired as C=1 would do.

D=<p8>          : Double ROI mode. Can be used to read out two independent
                  areas of the same size into one output image. This is useful
                  to gain speed due to dropping unneeded lines between two
                  areas of interest. Also field separation for interlaced mode
                  can be obtained. The top half of the output image consists
                  of the lines A, A+I, A+2*I, ..., A+N*I and the bottom half
                  consists of the lines B, B+I, B+2*I, ..., B+N*I. Thus the
                  resulting image size is (N+1)*2. Please see parameters
                  A=<p16>, B=<p16>, I=<p8> and N=<p16> for more details.
                    0:  Single ROI mode. Image size is (N+1) lines.
                    1:  Double ROI mode. Image size is (N+1)*2 lines.
                        Parameter B=<p16> specifies the address of the first
                        line of the second half. Please note that due to the
                        increased image size (N+1)*2 also the minimum frame
                        duration increases from (N+1) + 1 to (N+1)*2 + 1.

E=<p32>         : Exposure time. The time resolution depends on the prescale
                  value K=<p16>. Please note that the exposure time is only
                  active when the trigger mode M=<p8> is set accordingly.

F=<p32>         : Frame duration. The time resolution depends on the prescale
                  value K=<p16>. Please note that the frame duration is only
                  active when the trigger mode M=<p8> is set accordingly.

G=<p8>          : Digital gain.
                    0:  Gain factor 1.
                    1:  Gain factor 2.
                    2:  Gain factor 4.

I=<p8>          : Increment value of the line address counters A and B. After
                  processing each line this value is added to the current line
                  address. Valid range 1...FF (decimal: 1...255).

J=<p8>          : Configuration of synchronization output at pin 6 of the
                  control connector. This pin delivers RS232 voltage levels
                  (+/- 6 volts) with a delay of less than 800 ns. The logic is
                  negative, meaning +6 V = LOW and -6 V = HIGH.
                  <****_n*ss>
                        | \|
                        |  +-s: Signal source selection.
                        |          0:  Effective sensor exposure.
                        |          1:  Charge transfer pulse. Active for one line
                        |              duration at the end of exposure, end of
                        |              this pulse marks the end of exposure and
                        |              at the same time start of sensor readout.
                        |              In PIV mode (see M=<p8>) this pulse occurs
                        |              at the exposure end of only the first
                        |              image of each PIV pair.
                        |          2:  Effective sensor readout.
                        |          3:  Exposure phase. Contrary to 0 this setting
                        |              shows the "exposure phase" of the state
                        |              machine and not the effective exposure
```

```
                        |             of the sensor. This allows to synchronize
                        |             external devices even if the sensor is in
                        |             permanent exposure mode. See M=<p8> for
                        |             details about permanent exposure.
                        +-----n: Invert the logic levels of the sync output.

K=<p16>          : Timer prescale value. The basic clock frequency of 56 MHz is
                   divided by the prescale value (K+1) to generate the time base
                   for exposure time E=<p32> and frame duration F=<p32>. A value
                   of K=37 (decimal: 55) leads to a timer resolution of 1µs, for
                   example. To minimize jitter effects it is recommended to set
                   this value to a multiple of the current line duration, which
                   is K=A7 for single channel mode (e. g. S=0) or K=53 for
                   dual channel mode (e. g. S=3).

M=<p8>           : Exposure control.
                   <**ff_*pee>
                      \|  |\|
                       +  | +-e: Exposure timing mode.
                       |  |        0:  Continuous mode. The camera outputs images
                       |  |            as fast as possible in a free running
                       |  |            mode. The gap between two images is only
                       |  |            one line, thus the total frame duration
                       |  |            takes N+2 lines (or (N+1)*2 + 1, if double
                       |  |            ROI mode is active). The exposure time is
                       |  |            nearly equal to the frame duration.
                       |  |        1:  Image on demand mode (IOD). The exposure
                       |  |            is directly controlled by an externally
                       |  |            applied signal. Use parameter T=<p8> to
                       |  |            select the signal source. A rising edge at
                       |  |            the corresponding input starts exposure
                       |  |            synchronized to the line after the next.
                       |  |            If the rising edge occurs during idle (the
                       |  |            camera is not transmitting an image), then
                       |  |            the jitter is reduced. In this case
                       |  |            exposure will start with a constant delay
                       |  |            of about two line durations. The following
                       |  |            falling edge stops exposure in any case
                       |  |            and starts output of the image
                       |  |            synchronized to the next line. The next
                       |  |            exposure must start later than
                       |  |            (N+1)+1 line periods after the previous
                       |  |            rising edge. To be safe consider one line
                       |  |            jitter reserve, i.e. (N+1)+2. With D=1
                       |  |            setting replace the term (N+1) by (N+1)*2.
                       |  |        2:  Image on demand mode (IOD) with exposure
                       |  |            timer. The exposure time is controlled by
                       |  |            the parameter E=<p32>. Each rising edge of
                       |  |            an externally applied signal starts the
                       |  |            exposure. Use
                       |  |            parameter T=<p8> to select the signal
                       |  |            source. The next rising edge must
                       |  |            arrive later than (N+1)+1 line periods
                       |  |            after the previous rising edge. To be safe
                       |  |            consider one line jitter reserve, i.e.
                       |  |            (N+1)+2. With D=1 setting replace the term
                       |  |            (N+1) by (N+1)*2.
                       |  |        3:  Image on demand mode (IOD) with exposure
```

```
|   |            timer and frame duration timer. The
|   |            exposure time is controlled by the
|   |            parameter E=<p32>. The frame duration is
|   |            controlled by the parameter F=<p32>. Start
|   |            of the exposure can be synchronized to the
|   |            rising edge of an externally applied
|   |            signal. Use parameter T=<p8> to select the
|   |            signal source. Frame duration F=<p32> must
|   |            not be less than (N+1)+1 line periods
|   |            after the previous rising edge. To be safe
|   |            consider one line jitter reserve, i.e.
|   |            (N+1)+2. In the special case of K=A7 a
|   |            jitter reserve is not necessary, because
|   |            timer resolution is exactly one line
|   |            period. With D=1 setting replace the term
|   |            (N+1) by (N+1)*2.
|   +---p: Particle Image Velocimetry (PIV) mode. If
|          enabled, the camera outputs two images per
|          trigger event. If not in continuous mode the
|          time between two rising edges must exceed
|          1+2*((N+1)+1) line durations. The trigger
|          high duration should be less than N+1 line
|          durations, but at least 500 ns. After a delay
|          of one line duration plus 150 ... 250 ns
|          (depending on the used trigger input type) from
|          rising edge of the trigger input, the exposure
|          of the first PIV image ends and its readout
|          process begins. The exposure is permanently
|          active in this mode, thus for a usual PIV
|          application the first light strobe can also
|          start _before_ the trigger input event. In any
|          case it should end a few 100 ns before start of
|          readout. After a guard interval of a few 100 ns
|          ... 1000 ns the second light strobe may begin.
|          The exact position and length of the guard
|          interval depends on the allowable crosstalk
|          for the application and should be tested
|          individually. See J=<p8> for synchronization
|          output.
+------f: Exposure feature mode.
            0:  Standard mode.
            1:  Enhanced full well (3T) mode. The full
                frame shutter is not available in this
                mode. Instead, the sensor operates in
                rolling shutter mode with an effective
                shutter time equaling the frame duration.
                Thus a synchronized strobe light is
                recommended. Consequently any exposure
                time setting, controlled by E=<p32> or by
                external signal, is ignored. The light
                should flash between two
                image readout operations, which may be the
                duration of one line at highest possible
                frame rate. Decrease the frame rate
                accordingly, if longer exposure times are
                needed. Use exposure output (opto coupler
                at pins 12/13) or sync output (RS232
                driver at pin 6) for synchronization.
```

```
                                2:  Permanent exposure mode. Used to maximize
                                    the exposure time. If activated, the
                                    exposure time equals the frame duration.
                                    Consequently any exposure time setting,
                                    controlled by E=<p32> or by external
                                    signal, is ignored.
                                3:  Reserved.

N=<p16>          : This parameter sets the number of lines per frame. The
                   actual line count is N+1, thus the default of N=6BD results
                   into 1726 lines. If the double ROI mode is active (D=1)
                   the actual line count is (N+1)*2. Please consider this in
                   minimum frame duration calculations for the image on demand
                   (IOD) mode (see M=<p8>). See also parameters A=<p16>,
                   B=<p16>, D=<p8> and I=<p8> for more information regarding
                   sensor line addressing. Valid range 0...6BF (1 to 1728
                   lines).

S=<p8>           : Sensor mode control.
                   <****_*ccc>
                          \_|
                            +-c: Channel mode configuration.
                                    0:  Single channel mode (half pixel clock
                                        speed). Full line length of 2320 pixels is
                                        output at the Camera Link connectors O2/O1
                                        (or CL1/CL2). The data is mirrored at
                                        O4/O3 (not available in all variants), but
                                        note that the CC signals and SerTC/SerTFG
                                        are handled separately. Thus e.g. the
                                        trigger source selection (T=<p8>) and
                                        serial port configuration (s=<p8>) might
                                        need adjustments if only the connectors
                                        O4/O3 are connected to a frame grabber.
                                    1:  Dual channel mode (full pixel clock
                                        speed). The image is split vertically into
                                        a left and a right half. Thus each half
                                        has a horizontal size of 1160 pixels and
                                        is output separately on its own Camera
                                        Link 10-tap channel. The left half travels
                                        via the left Camera Link channel at the
                                        connectors O2/O1 (or CL1/CL2) and the
                                        right half travels via O4/O3 (not
                                        available in all variants) respectively.
                                    3:  Dual channel compatibility mode (full
                                        pixel clock speed). This mode basically is
                                        the same as S=1. For frame grabber
                                        compatibility reasons 40 pixel columns at
                                        the left and right side (of the full
                                        image) are dropped so that the line length
                                        of each half image is divisible by 16.
                                        The effective line length in this mode is
                                        2 x 1120 = 2240 pixels.
                                    5:  Same as mode 1, but with right image half
                                        via O2/O1 (or CL1/CL2) and left image half
                                        via O4/O3 (if available).
                                    7:  Same as mode 3, but with right image half
                                        via O2/O1 (or CL1/CL2) and left image half
                                        via O4/O3 (if available).
```

```
                                All other values are reserved.

T=<p8>          : Trigger source selection.
                    0:  None.
                    2:  OK1 at control connector.
                    3:  CC1 at O2 connector (or CL1).
                    4:  CC1 at O4 connector (if available).
                  All other values are reserved.

U=<p8>          : Metadata overlay and test image.
                  <***t_***m>
                       |    |
                       |    +-m: Metadata overlay mode.
                       |            0:  No overlay.
                       |            1:  Show metadata in each frame starting at
                       |                the first pixel of the first line.
                      +------t: Test image generator.
                                 0:  Normal image output.
                                 1:  Test image generator is active.

V=1             : Show model and firmware version information. Use V=2 for a
                  more detailed output.

W=<p8>          : Dark value offset. This value is added to the pixel data. It
                  is used to adjust the dark level and avoid clipping of pixels
                  to black in low light situations. The eight bits are aligned
                  to the lowest significant bit of the 10-bit raw pixel data
                  from the sensor. Thus if the digital gain is not active
                  (G=0), each increment of four increases the output grey level
                  just for one count.

X=1             : Store the current parameter configuration to the flash.

Y=1             : Show the current parameter configuration.

Z=1             : Load the factory default parameter configuration. The
                  saved configuration is only affected if you store the reset
                  parameter values with X=1 afterwards.
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